WATER QUALITY MONITORING PROTOCOLS AND SAMPLING GUIDELINES

LTIMP
(LAKE TAHOE INTERAGENCY MONITORING PROGRAM)

A SUBCOMMITTEE OF THE WATER QUALITY WORKING GROUP

SEPTEMBER 26, 2002

ACKNOWLEDGMENTS

The *Lake Tahoe Interagency Monitoring Program* (LTIMP) is a subgroup of the Water Quality Working Group and meets the first Wednesday of each month. LTIMP is well attended by a large selection of individuals and agencies, which makes it one of the most successful working groups in the basin. We would like to express gratitude to the group for participation, formal and informal, as technical advisors, commenter, and reviewers. The expanded LTIMP is listed below - without their assistance, preparation of these guidelines would not have been possible.

California State Parks

California Tahoe Conservancy

Caltrans

Camp Dresser and Mckee

City of South Lake Tahoe

Desert Research Institute

EDAW

El Dorado County Department of Transportation

Lahontan Regional Water Quality Control Board

Lake Tahoe Community College

Natural Resources Conservation Service

Nevada Department of Transportation

Nevada Division of Environmental Protection

Nevada Tahoe Resource Team, Nevada Division of State Lands

Placer County Public Works and Engineering Department

Sierra Nevada Community College

South Tahoe Public Utilities District

Tahoe Regional Planning Agency

Tahoe Resource Conservation District

Tahoe Research Group, University of California at Davis

University of Nevada, Reno

US Army Corp of Engineer

USDA Forest Service, Lake Tahoe Basin Management Unit

US Geological Survey, Water Resource Division, Nevada District

Washoe County Department of Public Works

Washoe Tribe of Nevada & California

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DOCUMENT CREDITS

This document was written by the various members of LTIMP over the past year. Many others have given input and advice through Basin agencies (see listing in the Acknowledgments section).

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9	U. S. Environmental Protection Agency Website

*'LTIMP members' refers to contributions of several members of the group during meetings throughout the year.

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1. PURPOSE AND OBJECTIVES

The purpose of this document is to provide guidelines and recommendations for implemen-ation of water quality monitoring in the Lake Tahoe Basin. It is a cooperative effort from the Lake Tahoe Interagency Monitoring Program (LTIMP). LTIMP was established in 1980 to develop integrated water quality research and monitoring strategies to support regulatory, management, planning, and research activities in the Lake Tahoe Basin. These guidelines are part of an effort to accomplish that mission. Additionally, this protocol and sampling manual is intended to streamline review and approval of monitoring plans that should be implemented in association with key projects, programs and studies. Hopefully the streamlining of these efforts will further close feedback loops that are necessary to advance the use of adaptive management strategies, such as project re-design towards attaining water quality thresholds.

The original key LTIMP members included the Tahoe Research Group-University of California at Davis (TRG), the U.S. Geological Survey (USGS), Lahontan Regional Water Quality Control Board (LRWQCB), Tahoe Regional Planning Agency (TRPA), and the Lake Tahoe Basin Management Unit, U.S.D.A. Forest Service (USDAFS). Since 1999 LTIMP has been operating as a subcommittee of the Water Quality Working Group, with an expanded membership (see inside of front cover).

Water quality monitoring in the Tahoe Basin is expanding through regulatory programs and research projects. There is a need to develop consistent and uniform protocols for unique constituents and monitoring programs in the Tahoe Region. The guidelines proposed in this document are intended to be used by individuals and agencies sampling and monitoring water quality within the Tahoe Region. This manual includes references to more specific protocols such as the U.S.G.S. National Field Manual and Caltrans Stormwater Sampling Protocols.

2. AGENCY MANDATES AND THRESHOLDS

The different agencies throughout the Lake Tahoe Basin established and enforce various mandates and thresholds. These mandates and thresholds have been developed to help protect and maintain the water quality of Lake Tahoe.

The Tahoe Regional Planning Agency Compact was adopted in 1982 and includes the environmental threshold carrying capacities for the Lake Tahoe Region. The Compact defines an environmental threshold as "an environmental standard necessary to maintain a significant scenic, recreational, educational, scientific or natural value…" Threshold standards are the primary guide to much of TRPA's planning and operation. Article V(d) of the TRPA Compact requires the Regional Plan to "provide for attaining and maintaining Federal, State, and local air and water quality standards, whichever are strictest" and identify the means and time schedule for these standards to be attained.

Resolution 82-11 adopted the official Environmental Threshold Carrying Capacities by the Governing Body of the Tahoe Regional Planning Agency. It consists of nine thresholds, one of which is water quality. The water quality threshold is further subdivided into seven indicators for improvements to water quality (Appendix A). These indicators are echoed in the Water Quality Management Plan for the

Lake Tahoe Region, known as the '208 Plan', in reference to the EPA Clean Water Act. The indicators and their standards are the basis for water quality improvements in the Tahoe Basin. As part of the 2001 Threshold Evaluation additional mitigation measures were recently added to focus on implementation of the Environmental Improvement Program (EIP); these are listed in Appendix 1 as EIP Units of Benefit. More information on thresholds and the 2001 Threshold Evaluation can be found on the TRPA website http://www.trpa.org, under Documents and Reports.

A. California Mandates and Thresholds

In California, the State Water Resources Control Board sets statewide policy for implementing state and federal water quality laws and regulations. In the Tahoe region, the Lahontan Regional Water Quality Control Board (LRWQCB) adopts and implements the Water Quality Control Plan (Basin Plan). The Basin Plan establishes water quality standards for surface and ground waters based on designated beneficial uses of water, and identifies narrative and numerical objectives to protect those uses. Water quality problems threatening beneficial uses are identified, along with recommended or required control measures and prohibitions to certain types of discharges. In addition, Lahontan issues National Pollutant Discharge Elimination System (NPDES) permits for a variety of discharges to surface waters, to the three local municipalities and Caltrans.

The Basin Plan includes Water Quality Objectives (Chapter 3), Implementation (Chapter 4), and Water Quality Standards and Control Measures for the Tahoe Basin (Chapter 5). See http://www.swrcb.ca.gov/rwqcb6/ for a copy. Lake Tahoe is one of California's few designated Outstanding National Resource Waters (ONRW) under federal anti-degradation regulations (40 CFR § 131.12 and 48 Fed. Reg. 51402). The ONRW designation does not allow permanent or long-term reduction in water quality.

B. Nevada Mandates and Thresholds

In Nevada, the Nevada Division of Environmental Protection sets statewide policy for implementing state and federal water quality laws and regulations. Two main Bureaus are responsible for the protection of the quality of Nevada's Waters; these are the Bureau of Water Quality Planning (BWQP) and the Bureau of Water Pollution Control (BWPC).

The Bureau of Water Quality Planning (http://ndep.state.nv.us/bwqp/bwqp01.htm) is responsible for several water quality protection functions, which include collecting and analyzing water data, developing standards for surface waters, publishing informational reports, providing water quality education and implementing programs to address surface water quality. The BWQP is divided into three branches: Water Quality Monitoring, Water Quality Standards and Nonpoint Source Program.

The Water Quality Monitoring Branch is responsible for the State of Nevada's water quality monitoring program. This branch maintains and updates water quality data for EPA's national water quality database (STORET), and is responsible for preparation of Nevada's Water Quality Assessment Report, which is required under Section 305(b) of the Clean Water Act (CWA). To ensure federally permitted activities do not cause water quality impairment, this branch issues certifications under Section 401 of the CWA. Additionally, this branch reviews environmental impact statements, environmental assessment documents, clearinghouse documents and permits for the Army Corps of Engineers, the Federal Energy Regulatory Commission and the Nevada Division of State Lands.

The Water Quality Standards branch is responsible for developing and reviewing water quality standards; determining wasteload and load allocations from point and nonpoint sources (respectively); and developing Total Maximum Daily Loads (TMDLs). Water quality management plans and the "impaired waters listing" required under sections 208 and 303(d) of the Clean Water Act, as well as the Continuing Planning Process, are prepared by this branch. Frequent violations of standards for Lake Tahoe and a number of its tributaries will result in their listing on Nevada's 303(d) List for 2002.

The Nonpoint Source (NPS) Program is responsible for all NPS planning, including developing and updating the state management plan, the state assessment report and the Best Management Practices Handbook. Using grant monies available under Section 319(h) of the Clean Water Act, this branch solicits, selects and manages projects that help to control and minimize NPS pollution. A number of these projects feature restoration actions or the implementation of best management practices (BMPs). Other projects focus on public outreach and education that promote environmental stewardship. The NPS staff also coordinates activities with other agencies to minimize pollution derived from land uses that have a high potential for NPS generation.

The Bureau of Water Pollution Control (http://ndep.state.nv.us/bwpc/bwpc01.htm) is responsible for protecting the quality of Nevada waters from the discharge of pollutants. This is accomplished by issuing discharge permits, which define the quality of the discharge necessary to protect the quality of the waters of the State, enforcing the state's water pollution control laws and regulations, and by providing technical and financial assistance to dischargers. The BWPC issues National Pollutant Discharge Elimination System (NPDES) Permits for discharge to surface waters, ground water permits for discharges that may impact subsurface waters, Underground Injection Control (UIC) permits for injection through wells, and Stormwater Permits. Additionally, the BWPC performs engineering reviews of the designs of permitted facilities, inspects permitted facilities and investigates violations of water pollution statutes and regulations.

3. WATER QUALITY ISSUES

In the Watershed Assessment published in May 2000, defined water quality issues in terms of science-based questions that would lead to adaptive management decisions. This process of identifying research needs to provide a roadmap for the funding of monitoring and projects was then used by the Water Quality Working Group and the Science Advisory Group to refine and prioritize these needs into thirteen water quality issues. They generally include such topics as the need for prioritization of restoration projects, the feedback of research and monitoring findings to the design of new projects, the implementation of the Environmental Improvement Program (EIP), and review of water quality standards and thresholds. These issues formed the basis for Budget Proposals to the State of California for funding through Lahontan and TRPA and others. The LTIMP group reviewed the issues and tried to provide specific tasks under the issues to focus research and monitoring efforts.

4. ADAPTIVE MANAGEMENT

Coordinated interagency efforts for natural resource management in the Tahoe Basin have been organized under the adaptive management framework. A detailed application of this approach for the Tahoe Basin has recently been described in the Lake Tahoe Watershed Assessment (January 2000, Vol. 1 Chapter 7). To summarize from this document, the adaptive management approach is designed to speed rates of development and implementation of appropriate resource management strategies through research and monitoring. A critical element of this process is the constant refinement of management strategies through an iterative process of monitoring, data evaluation, decision-making, and management action.

The main objective of an adaptive management approach is to provide timely feedback on the relative effectiveness of management actions, so that modifications in design or approach can be made quickly to achieve stated goals. In the case of Lake Tahoe, research has shown that an immediate reduction of nutrient input into the lake may take up to thirty years to see the resultant clarity changes. So, time is of the essence and management must respond quickly to lessons learned in earlier stages of this process. The cost of reversing this trend may become prohibitive if not accomplished within the next ten years.

The adaptive management framework is designed to achieve this efficiency through an iterative cycle that is graphically demonstrated in Figure 1. The key elements of this cycle are (1) the identification of information needs, (2) acquisition and assessment of that information, (3) an evaluation and decision-making process, followed by (4) management action. This cycle is then repeated with an updated identification of information needs to evaluate the effectiveness of management action. The primary role of science in adaptive management is to provide an integrated approach to research and monitoring that crosses disciplines at appropriate scales and provides new information of relevance to resource managers. It should also assist in the interpretation and application of that information by working with managers to develop adaptive management strategies, experiments and results oriented monitoring. New information through research and monitoring is often critical to making appropriate decisions in resource management.

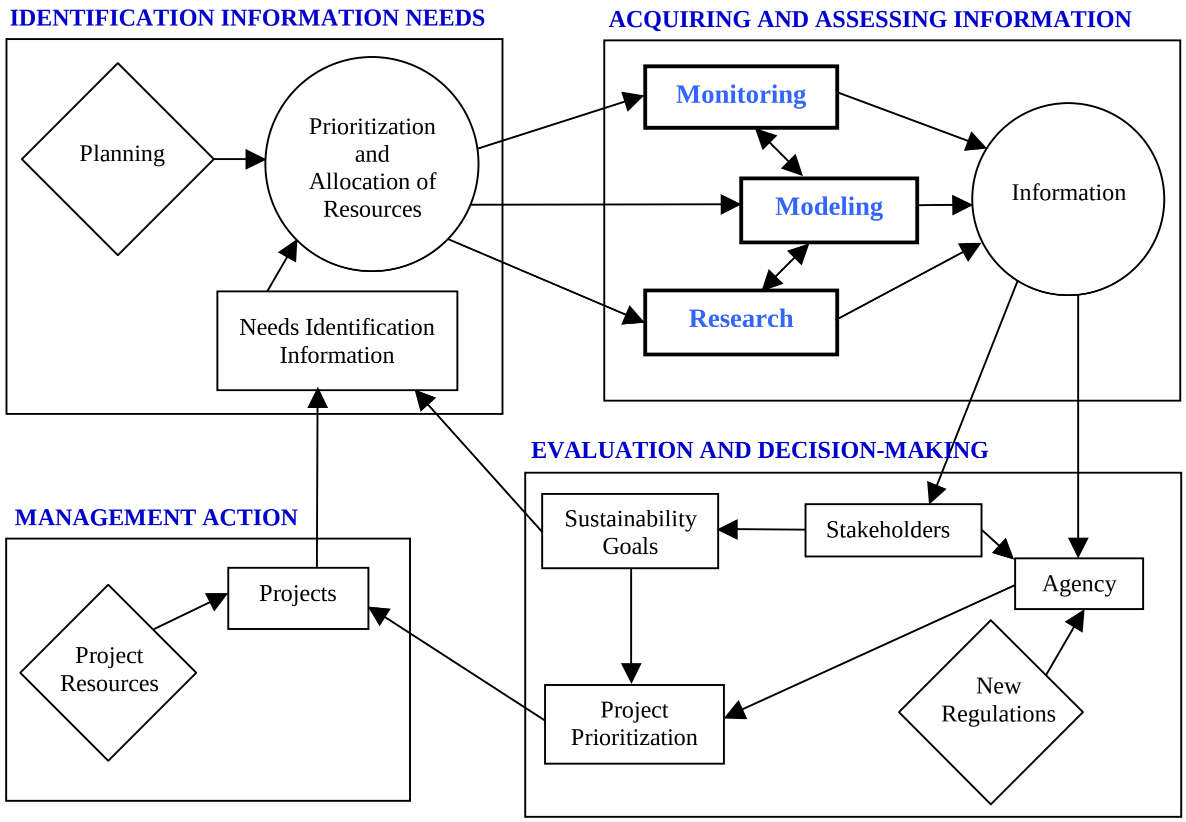

Figure 1: A schematic diagram of an adaptive management planning cycle (Lake Tahoe Watershed Assessment: Volume 1, p. 692 (USDAFS, 2000))

5. PRIORITY CONSTITUENTS AND PARAMETERS

Nutrients, trace elements and suspended sediments are the main constituents of concern in water quality monitoring for the Tahoe Basin. Although other compounds may be important or even regulated in some cases (e.g. MTBE, PCBs or other organic contaminants), they are not routinely monitored at this time and will not be considered in this discussion. Appendix B lists several tables grouped by categories of parameters.

In the compilation of this manual, several LTIMP meetings have centered on the lab constituent list and reporting levels. The appendix cites reporting detection limit as the minimum level for accurate detection of the low nutrient levels often seen in Lake Tahoe. One of the primary goals of these guidelines is to insure consistency and comparability of lab data and methods. The EPA referenced lab method is only an example of a more commonly used method, and does not preclude the use of other methods. Our goal is for the highest accuracy at the lowest reporting limit that can be defensible, repeatable, and comparable to other monitoring.

Nitrogen and phosphorus are the major nutrients that typically limit algal growth in Lake Tahoe. Complex biogeochemical cycles exist for both of these elements and they occur in many different forms, not all of which are clearly identified. For purposes of water quality monitoring, however, scientists typically recognize a few distinct analytic classes and measure the concentrations within these groups.

For nitrogen, the main groups are dissolved ammonium (DNH_4), dissolved nitrate (DNO_3), and total nitrogen (TN). The total nitrogen is typically measured after a Kjeldahl digestion, and thus consists of both the total organic and ammonium nitrogen. It is represented as total Kjeldahl nitrogen (TKN). When this digestion is done on filtered water samples (< 0.45 microns), the analysis represents dissolved Kjeldahl nitrogen (DKN). However, the difference between TKN and DKN is frequently less than analytic variance in their measurements, so TKN is the more commonly measured constituent. It should also be noted that analytic methods for nitrate usually include nitrite. Unless reported differently, therefore, a dissolved nitrate concentration should be considered the sum of nitrate and nitrite concentrations in that sample.

Phosphorus is also reported in several analytically defined groups, with total phosphorus (TP) and soluble reactive phosphorus (SRP) being the most commonly measured. Soluble reactive phosphorus methods measure mostly the dissolved orthophosphate fraction, which is considered the form readily available for algal uptake. Sometimes total dissolved phosphorus concentrations are reported (DP). As with DKN, these are the same as analyses for total concentrations but done on appropriately filtered samples.

Currently, the focus in the Tahoe Basin is on controlling phosphorus inputs to the lake. Bioassays have indicated that Lake Tahoe has shifted to being predominately phosphorus limited for mixed community algal growth thus directing the focus to controlling phosphorus. However, there is still a high occurrence of co-limitation, so control of nitrogen input should not be abandoned.

Recently, it has been recognized that finely divided sediments remain in suspension for long periods of time in Lake Tahoe. This also contributes to a reduction in lake clarity, and may contribute a disproportionate amount of nutrient loading as well (due to surface adsorption). Therefore, monitoring studies have begun to focus on suspended sediment concentrations, turbidity and particle size distributions. In addition to nutrients, it is thought that particle sizes less than 20 microns are particularly important in nutrient loading and clarity loss. So, when practical, particle size classifications should distinguish between size fractions that include between 20 to 63 microns.

Other elements are measured on occasion for specific projects. These include selected metals of interest in storm water such as arsenic, cadmium, chromium, copper, nickel, zinc, lead, and iron. While some of these may have effects on algal growth rates, as micronutrients, others are considered to act as algaecides or may be toxic to higher organisms. Iron is most frequently reported as biologically available iron (BaFe), which includes the dissolved inorganic and some organic iron fractions.

Physical parameters in water quality monitoring will not be discussed in depth in this manual due to past and other exhaustive information and knowledge regarding them. These parameters are necessary for interpreting the nutrient and chemical loading data. Discharge, gage height, air temperature, precipitation rates and weather conditions influence water runoff volume and its chemical composition. Other factors like pH, dissolved oxygen and water temperature impact the water quality directly. Specific conductance is considered as a monitoring parameter to be a measure of total dissolved ionic concentrations. Turbidity can be used as a surrogate for suspended solids, although it has been shown to be very site specific.

Last of all, standardized and comprehensive field data sheets are essential for reliable water quality sampling. There is no substitute for being in the field and directly observing how various landscape or disturbance factors impact water quality. The field data sheet provides a conduit for this information to enter into the data interpretation process.

6. REFERENCES FOR DESIGNING A SAMPLING PROGRAM

The following is a collection of references and documents related to sampling programs. It is advisable to prepare a 2-5 page sampling plan, whether or not it is required of your agency or funding source. It is also advisable to refer to the plan quarterly to ensure compliance with the plan. Many of these documents are available as PDF files on the Internet.

A. Sampling Manuals

U.S. Geological Survey *Field Methods For Measurement Of Fluvial Sediment* (Edwards and Glysson 1988).

This reference contains two major sections: The “Sediment-Sampling Equipment” section encompasses discussions of characteristics and limitations of various models of depth- and point-integrating samplers, single-stage samplers, bed-material samplers, bed-load samplers, automatic-pumping samplers, and support equipment. The “Sediment-Sampling Techniques” section includes discussions of representative sampling criteria, characteristics of sampling sites, equipment selection relative to the sampling conditions and needs, depth- and point-integration techniques, surface and dip sampling, determination of transit rates, sampling programs and related data, cold-weather sampling, bed-material and bed-load sampling, measuring total sediment discharge, and reservoir sedimentation rates.

U.S. Geological Survey *National Field Manual for the Collection of Water-Quality Data* (USGS, 1998).

This reference includes preparation, equipment, cleaning, collection, processing, measurements for surface and groundwater sampling, biological indicators, and bottom materials.

Caltrans Guidance Manual: Stormwater Monitoring Protocols (Caltrans 2000).

Website: Caltrans - Annual Report and Public Workshops.

This reference contains sections on grab samples and automatic samplers. Section 5 “Selection Of Monitoring Methods and Equipment” contains write-ups on Sample Collection Methods (5-1) and Sample Collection Equipment (5-4). Section 7: “Equipment Installation and Maintenance” contains a section on Automated Samplers (7-6), and Section 10: “Sample Collection” contains a section on Grab Sample Collection (10-4).

U.S. EPA *Compendium Of ERT Surface Water And Sediment Sampling Procedures* (US EPA 1991).

This reference has a section applicable to the collection of representative liquid samples: Section 2.0 Surface Water Sampling: SOP #2013.

U.S. EPA *Nutrient Criteria - Technical Guidance Manual – Rivers and Streams*: U.S. EPA publication EPA-822-B-00-002, p. 152 and p. 88 appendix. (2000). http://www/epa.gov/ost/criteria/nutrient/guidance/rivers/index.html

This reference covers stream system classification, select variables, sampling design for new monitoring programs, building a database, analyze data, criteria development, management programs, monitoring & reassessment of nutrient criteria ranges, case studies, methods of analysis for water quality variables, statistical tests & modeling tools.

B. Setting up Sampling Programs

National Resources Conservation Service *National Handbook of Water Quality Monitoring* (NRCS 1996).

Ground-water Data-collection Protocols and Procedures for the National Water-Quality Assessment Program: Selection, installation, and documentation of wells, and collection of related data. USGS Open-File Report 95-398 (Lapham, W. W. and others, 1995).

This reference covers selection, installation, and documentation of groundwater wells.

U.S. Geological Survey *Quality Control Design for Surface Water Sampling in the National Water Quality Assessment Program* (Mueller et al, 1997).

U.S. Geological Survey *Guidelines and Standard Procedures for Continuous Water-Quality Monitors: Site selection, field operation, calibration, record computation, and reporting* (Wagner and others, 2000).

C. Equipment

U.S.D.A. Forest Service *Field Methods for Measurement of Fluvial Sediment* (Edwards and Glysson, 1988).

This reference contains a section on equipment.

U.S. Geological Survey *National Field Manual for the Collection of Water-Quality Data* (USGS, 1998).

This reference also contains a section on equipment.

D. Sample Collection and Processing

U.S. Geological Survey *National Field Manual for the Collection of Water- Quality Data* (USGS, 1998) and Open-file reports; U. S. Geological Survey.

Protocol for the collection and processing of surface-water samples for the subsequent determination of inorganic constituents in filtered water (Horowitz, A.J. and others, 1994).

Field Guide for collecting samples for analysis of volatile organic compounds in stream water for the National Water-Quality Assessment Program (Shelton, L.R., 1997).

Guidelines for collecting and processing samples for streambed sediment for the analysis of trace elements and organic contaminants for the National Water-Quality Assessment Program (Shelton, L.R., and Capel, P.D., 1994).

E. Collection of Discharge Measurements, Stage Measurement, Gage Operations, and Computation of Continuous Record of Stream flow at Stream Sites

U.S. Geological Survey TWRI Book 3, Chapter A8, *Discharge measurements at gauging stations* (Buchanan, T.J. and Somers W.P., 1976).

U.S. Geological Survey TWRI Book 3, chapter A7, *Stage measurement at gauging stations* (Buchanan, T.J. and Somers, W.P., 1978).

U.S. Geological Survey TWRI book 3, chapter A6; *General Procedure for gauging streams* (Carter, R.W. and Davidian J., 1977)

U.S. Geological Survey TWRI book 3, chapter A13, *Computation of continuous records of streamflow* (Kennedy, E.J., 1983).

F. Sample Collection and Processing of Fluvial and Bed Sediment

U.S. Geological Survey Open-file reports; *Field Methods for Measurement of Fluvial Sediment* (Edwards, T.K. and Glysson, G.D. 1988).

U.S. Geological Survey *National Field Manual for the Collection of Water-Quality Data* (USGS, 1998).

G. Sediment Lab Methods

There have been several discussions in the last year about sediment methods in light of a recent USGS report, "Are Total Suspended Solids and Suspended Sediment Concentrations in Open Channel Flows the Same Data Type," (Glysson, G.D. and Gray, J.R., 2001). Bruce Warden, a chemist from Lahontan RWQCB, wrote a brief comment on this report, and encourages more documentation of methods used. This comment can be found on the last page of Appendix B, Sample Constituents.

The USGS website for recent highway runoff studies at http://ma.water.usgs.gov/FHWA/products/ofr00-491.pdf is also very useful. The LTIMP group has begun an initial comparison of total suspended solids (TSS) and suspended sediment concentrations (SSC) on a few projects, and will be discussing this further in the next year.

U.S. Geological Survey TWRI Book 5, chapter C1, *Laboratory Theory and methods for sediment analysis* (Guy, H.P., 1977).

H. Sample Collection and Processing of Groundwater Samples

U.S. Geological Survey *Ground-water data-collection protocols and procedures for the National Water-Quality Assessment Program: selection, installation, and documentation of wells, and collection of related data* (Lapham, W. W. and others, 1995).

I. Sample Collection with Automatic Samplers

The ability to collect useful information about suspended sediment transport and water discharge is dependent on the timing and frequency of data collection during storms. All river systems, particularly smaller watersheds that respond very quickly to rainfall with peak discharges often occurring shortly after the onset of precipitation, benefit from automated data collection.

Although it is possible to rely solely on manual measurements, important storm flows are infrequent and difficult to predict, and when they do occur, trained personnel may not be available to collect the required information.

Most of the suspended sediment in the Tahoe Basin is transported during storms (approximately 86% of the estimated sediment transport in 1999 occurred during the 8 largest storms). Infrequent, systematic manual sampling will not provide adequate information to make credible suspended sediment load estimates under these conditions. As of yet, there is no reliable method to measure suspended sediment concentrations automatically or continuously in the field.

A common method to estimate suspended sediment loads relies on water discharge to determine the sampling frequency during storms. Usually water discharge is not a good predictor of sediment concentration for rivers and streams that transport the bulk of their sediment load as fines because the delivery of sediment to the channel from hill slopes, roads, and landslides is highly variable. For rivers that transport mostly sand, water discharge and concentration are more closely coupled because the transport of sand particles depends on stream power and the availability of sediment stored in channel bars and flood plains.

A sampling scheme that employs a parameter well correlated to suspended sediment concentration, such as turbidity, can improve sampling efficiency by collecting physical samples that are distributed over a range of rising and falling concentrations (see Lewis and Eads 1996 and 1998). The resulting set of samples can be used to accurately determine suspended sediment loads by establishing a relationship between sediment concentration and turbidity for any sampled period and applying it to the continuous turbidity data (Eads, 2000).

Appendix C is an excerpt from the NRCS Sampling Handbook in relation to sample types. For automatic samplers the choice between time weighted and flow weighted composite sampling are especially important, and is dependent on project objectives. Currently LTIMP is in the process of developing guidelines for the sampling from continuous devices, but there is insufficient data at this time to establish a universal protocol, or if one is even appropriate. The recommendation at this time is to budget for initial sampling screening to characterize the site, with yearly review and adjustments as needed.

Appendix D contains information on the automated samplers installed by El Dorado County Department of Transportation (EDOT) and the City of South Lake Tahoe. These automated samplers were patterned after the installations by Eads and improved upon to meet site conditions on streams and rivers in the Tahoe Basin.

J. Laboratory Sample Analysis Costs

The cost to conduct water quality monitoring for a project varies depending on the type and number of constituents, equipment, and organization administering the work. Appendix E contains cost comparisons of primary constituents for five different labs used by organizations in the Tahoe Basin. The price varies among the different labs, as well as, by the type of constituent. Appendix E also contains examples of costs for several Tahoe Basin projects form the last few years.

7. MONITORING OBJECTIVES

The major objective of monitoring should be to provide data to document existing conditions and evaluate the impacts of proposed management actions, Best Management Practices (BMPs). Due to natural variability it is impossible to collect sufficient data to either establish the true existing conditions or to fully determine the impacts of BMPs. Thus to efficiently and effectively determine both existing conditions and evaluate the impacts of proposed management actions, it is prudent to calibrate models to calculate and forecast events and evaluate the impacts of proposed management actions. The calibration and validation of models is contingent upon monitoring. Hence, the two feed on each other and the result is enhanced monitoring and modeling. This section includes constituents to be monitored, priorities, and sampling regimes for various types of projects.

A. BMP Monitoring

The instrumentation and protocol for monitoring BMPs should reflect the Priority Constituents and Parameters for Lake Tahoe discussed in section 5 of this Guidance document. The primary rational should be developing monitoring protocol that will accurately assess the loadings of nutrients and fine sediments affecting the clarity of Lake Tahoe. Not only should these loadings be quantified by source but the timing of releases should also be documented in order to properly design BMPs to effectively reduce loadings.

B. Water Quality Treatment Basins

Historically, storm water detention ponds and infiltration basins have been utilized as standard BMPs. Management of existing wetlands to trap pollutants and enhance water quality has more recently gained popularity. If sized appropriately detention ponds and infiltration basins allow larger sized sediment and particulate materials to settle out. Additional amounts of nutrients are removed as stormwater percolates through the soil to the subsurface ground water. As long as there is standing water in the basin, a portion of the particulate nutrient load and suspended sediments will settle to the basin floor by gravity. As water is forced through the soil matrix during percolation an additional percentage of the remaining pollutant load will be removed. Sediment and nutrient removal occurs through adsorption, precipitation, trapping, straining, and bacterial degradation or transformation. The wetland cell treats by providing a relatively long residence time for reduction of both particulate and dissolved constituents through physical, chemical, and biological processes.

The benefits of a detention pond/infiltration and wetland two-cell system include the following:

- nitrogen can be biologically converted to nitrate and permanently removed via denitrification (in both basins and in wetlands);
- phosphorus (typically associated with sediment load) can be partially removed by simple sedimentation and soil filtration;
- and suspended sediments and total iron are typically reduced.

To meet local permitting rules basins are typically sized for a one-inch storm from the "project area," the project proponent's (e.g., County, City) paved right-of-way. This sizing assumes other properties in the project area have been BMPed to retain one-inch storms on site, which is recognized is often not the case.

Suggested Monitoring Procedures (from Tahoe City basin monitoring proposal):

The Tahoe City system consists of a detention basin releasing to an artificial wetland.

- Measure runoff inflow of the detention basin (measurements can be made as frequently as once per week and during significant storm events).
- On a regular basis, monitor hydraulic flow through the entire system (including flow to the wetland from the detention basin, outflow from the wetland, outflow from the basin).
- At a minimum, measure nitrogen (nitrate and ammonium), phosphorus (ortho-P [SRP] and TP) and total suspended solids in the inflow water, as well as at the outlet of the detention basin in route to the wetland, a mid-point in the wetland, and at the outlet of the wetland. Since phosphorus has been identified as the most critical limiting nutrient to algal growth in Lake Tahoe, these analyses, along with TSS should be given top priority.
- Additional samples can be taken at each of the sites discussed above for major runoff periods including: rainfall on dry ground (e.g., fall rainstorms and summer thunderstorms), rain-on-snow, and snowmelt.
- Sediment cores and visual observation can determine sediment volume and distribution in the detention basin and wetlands.
- Selected samples from inflow runoff and standing water in the facility can be analyzed for particle size and possibly phosphorus content.
- Water temperature, sediment temperature, and dissolved oxygen can be measured.
- Visual observations should be made in both basins for bank erosion resulting from wind waves or from changes in surface elevations.
- Visual observations should be recorded on a formalized data sheet following each project site visit. Photographs and videotapes can also be taken as appropriate.

Research Questions

The following is a list of topics and questions we hope to address with the proposed monitoring and research program. As the project develops, we may find that some of these issues may be beyond the scope of this contract. At the same time, we may find that the collected data suggests that alternative avenues of inquiry should be followed. The list below is intended to serve as a working guideline for this monitoring effort.

- Quantify hydraulic, nutrient and sediment loading into the wetland basins at various time scales, ranging from annual and monthly estimates to loading rates resulting from specific runoff events.
- Define the relationship between magnitude of runoff, residence time, water depth, and the volume to bottom-area ratio.
- Characterize particle size distribution of sediments entering and leaving system.
- Determine how sediment is transported within the system. What portion settles rapidly near the inflow relative to the portion that remains suspended?

- Investigate the extent to which sediment is resuspended off the bottom (either by wind/ wave action or turbulence at the inflow).
- Determine the efficiency of nutrient and sediment removal in the artificial wetlands basin. This will focus on removal efficiency related to:
  - storm intensity and frequency;
  - various water quality constituents, i.e., nitrogen, phosphorus and sediment;
  - dissolved vs. particulate constituents;
  - season;
  - snow conditions.
- Determine relationship between removal efficiency and [i] temperature, [ii], residence time, [iii] concentration, [iv] bottom contact, and [v] vegetation.
- Determine relationship between hydraulic operation and project maintenance.
- Identify the preferred hydraulic and maintenance plans that will optimize system performance.

C. Best Management Practices for Non-Point Source Discharge Control

EPA's Office of Water has recently added "Best NPS Documents" to its Non-Point Source (NPS) Website. Subject areas include Agriculture, Forestry, Marina, Urban, Stream Restoration, Nonpoint Source Monitoring and Funding. These can be found at:
http://www.epa.gov/owow/nps/bestnpsdocs.html
According to the Tahoe Regional Planning Agency's (TRPA's) Code of Ordinances, property owners are required to infiltrate the volume of a 20 year/1 hour storm that is generated from their property on their property (Subsection 25.5.A). This ordinance includes residential, commercial, and public service properties in the Lake Tahoe Basin. Therefore, new parking lots in the Lake Tahoe Basin need to be designed and built with appropriate and recommended BMPs. Many properties with existing parking lots that have inadequate BMPs will need to be retrofitted under the timeline set forth in Chapter 25 of the Code of Ordinances.

The BMPs will need to be in accordance with TRPA's Handbook of Best Management Practices, which is currently being updated. Recommended BMPs, like any technology, need to be updated as innovations occur and designs are improved. These improvements are reflected in greater pollutant removal efficiencies. Because the handbook has not been updated since 1988, improvements in BMP design need to be relayed through specialists on the Erosion Control Team or the Long Range Planning Division of TRPA. The new handbook will include the best available technology to date, and should be considered a "living document" that will be updated as needed.

A matrix to determine when a parking lot will necessitate an oil/grease separator or interceptors with appropriate pre-treatment systems is also being developed. TRPA and Lahontan Water Quality Control Board are developing these documents collaboratively. In addition, the ordinance passed in 1999 for Source Water protection will require projects that have potential for impact to nearby (600 foot radius) drinking water sources to insure appropriate BMPs, (SWAPP report, TRPA website).

BMPs include more than just structural and non-structural practices implemented on the ground. They also include other non-point source control measures under the Environmental Protection Agency (EPA) such as creating a Formal Storm Water Pollution Prevention Plan and preparing to respond to accidental spills. Therefore, additional non-point source control measures are currently recommended for parking lots:

- Development of a Stormwater Management Plan; complete with a Spill Contingency Plan and BMP Maintenance and Monitoring Plan for commercial and public service parking lots (El Dorado County Environmental Management has one);
- Quarterly sweeping with a high efficiency vacuum street sweeper to clean up potentially contaminated sediments that are then properly disposed of;
- TRPA-Approved BMP Design and Installation; which may include oil/grease separators, pretreatment vaults, curb and gutter or drop inlets, and secondary treatment systems (i.e. retention basins, vegetated swales, etc.) designed to contain at least the 20 year/1 hour storm runoff;

- Maintenance and monitoring of treatment systems based on design;
- Delineation of appropriate uses (i.e. not washing vehicles/equip on parking area unless there is a treatment system to prevent the flush of contaminants from parking surfaces into surface waters);
- Containment of potential contaminants on industrial staging lots with "source separation" (EPA, 1998), which utilize curbing, containment dikes, and other separating devices to prevent staged or stored contaminants from entering treatment systems;
- Property owner education;
- Vehicle and equipment fueling, maintenance, and staging plan to provide the appropriate BMPs for industrial lots with high potential for spills and contamination due to the nature of the use of the lot;
- Snow storage areas and appropriateness for locations.

Note: The appropriate BMPs for a parking lot will depend on many factors. Therefore, the appropriate BMP system will need to be determined by a qualified professional on a case-to-case basis. The forthcoming updated Hand-book of Best Management Practices as well as the matrix to determine when certain BMPs will be required on a parking lot will assist project planners in anticipating what will be required.

In the interest of adding more specific information on parking lot treatment systems and their effectiveness, please see the table of excerpted data from the report titled "Investigation of Structural Control Measures for New Development," prepared by Larry Walker Associates in November 1999, and prepared for the Sacramento Stormwater Management Program (Appendix F). Unfortunately, as noted by Walker, BMP effectiveness studies to date have been inconsistent and data reporting has been unreliable. The column "Approval Recommendation" reflects this; if a treatment system has not been tested adequately, Walker and Associates gave it a rating of "not acceptable" until further tests have been completed with correct scientific protocol. Appendix F also shows parking lot monitoring protocols, with the TRPA Discharge Limits for Surface and Groundwater.

Environmental Protection Agency Office of Ground Water and Drinking Water. 1998. *Guidance on Storm Water Drainage Wells, Chapter 7.0 Operational Best Management Practices* http://www.epa.gov/reg5oh20/storm/newchap7.htm)

Strecker, E. and Reininga, K. 1999. *Integrated Urban Stormwater Master Planning.*

Strecker, E., Quigley, M. and Urbonas, B. *Determining Urban Stormwater BMP Effectiveness* http://www.asce.org/peta/tech/nsbd01.html

TRPA. *Handbook of Best Management Practices.* 1988

Walker, Larry and Associates. 1999. *Investigation of Structural Control Measures for New Development*. Prepared for: Sacramento Stormwater Management Program.

D. Golf Courses/Large Turf Areas

Golf courses and other large turf area (schools and ball playing fields, condo complexes, large residential parcels) have the potential to contribute large amounts of fertilizer to both ground water and surface water. At present Lahontan Water Quality Control Board regulates the ten golf courses in California through waste discharge requirements. TRPA requires water quality monitoring at golf courses in Nevada, through conditions of their permits.

The permits written by Lahontan have recently been revised, and reflect changes as a direct result of the monitoring data. For example, the Tahoe City permit requires sampling only once a year due to the results of ten years of data showing a properly managed chemical and irrigation plan that maximizes good turf characteristics while minimizing potential for transport of contaminants to surface and ground waters. Other irrigation plans sampling schedule are far more rigorous.

Many of the new commercial and larger residential developments have fertilizer management plans as a condition of their permits. Monitoring should include groundwater samples and off site runoff as well as surface water sampling of any nearby stream or creek.

Non-commercial turf areas are currently not part of any permitting process and monitoring is voluntary. The Resource Conservation Districts provide assistance and education to private landowners as part of their Backyard Conservation Program. The recent publication *Home Landscaping Guide for Lake Tahoe and Vicinity* includes a chapter on the proper types and amounts of fertilizers. A recommendation of the 2001 Threshold Evaluation is for an increased reduction in fertilizer use and elimination of fertilizer use in SEZ's and the shorezone.

E. Grazing/Confined Animals

The issue of livestock grazing on public or private lands is addressed in Chapter 73 of the TRPA Code of Ordinances, adopted in July 1987, which was drafted from Volume I of the Water Quality Management Plan (208 Plan). The 208 Plan identifies livestock grazing and confinement facilities as potential contributors to water quality degradation. Chapter 73.2 deals with grazing and sets standards for use and streambank protection. A subsection requires a grazing management plan, and that confinement facilities be brought into compliance with BMPs by July 1, 1992.

In both the 1991 and 1996 Threshold Evaluations, the need to revise and implement the ordinance for BMP requirements for both new and existing grazing operations, coordinate implementation efforts with the USDAFS, and expand BMP monitoring. Through the process of the ordinance revision, a Grazing Technical Advisory Committee formed in 1996, and worked to add the Amendment to Chapter 73, adopted by the Governing Board in January 1999. The primary focus was related to livestock facilities, although any pen or confinement of any animals should require similar BMPs.

In terms of water quality monitoring, the primary focus is the installation and subsequent effectiveness of appropriate BMPs. On large-scale operations, such as corrals for concessionaires that rent horses, or cattle grazing operations, monitoring for water quality should include fecal coliform and turbidity, as well as bioassessment surveys to determine riparian habitat health. The bulk of monitoring in the Tahoe Basin has been by the USDAFS through grazing allotments and LWRCB for public health violations.

F. Visual/Photo Monitoring

Visual and other sensory observations and photo monitoring should not be overlooked as cursory and inexpensive methods of monitoring. Many NPDES permits and project funders require a visual monitoring component. The basis for many citizen monitoring groups is the Stream/ Shore Walk Visual Assessment observation sheet (Appendix G: California Stream and Shore Walk Visual Assessment.) Observations should be made, at a minimum, on a monthly basis. Observational data can include color, odor, presence of oil or tar, trash, foam, turbidity, percent snow cover, and many others specific to a monitoring site. Photo monitoring should always be recorded with a photo log with the following information: date, time, person taking picture, general and specific location, (South Lake Tahoe, Angora ECP, culvert at NE corner of Circle View), orientation (N, S, E, W, i.e. looking east), point of reference and permanent landmark or any other info. Ideally, you would want another person to be able to take the same picture based on the information you log.

8. RELATED MONITORING

A. Slope Stabilization and Revegetation

Although this is a guideline primarily for water quality, it is recognized that an integral part of water quality improvements involves revegetation. In a natural, undisturbed watershed, runoff and snowmelt generally infiltrate into the ground, whereas, in a disturbed area, impervious surfaces allow the water to redirect and collect sediment and nutrients. The success or failure of the revegetation effort can mean the success or failure of the entire project.

The importance of revegetation was recognized recently in the adoption of Objectives and Guidelines for Revegetation Success under the Nevada Tahoe Bond Act. This brief document provides a plan for revegetation specifications for any project funded by the Nevada Bond Act. Appendix H includes vegetation monitoring submissions from the following sources, in this order:

Etra and Reynolds. M*onitoring for Revegetation, Erosion Control, Restoration and Water Quality Improvement Projects in the Lake Tahoe Basin*, Oct. 20, 2000.

Hogan, Michael, *Plant Monitoring for Upland Restoration Projects in the Lake Tahoe Basin*, Sept. 17, 2000.

There is increasing interest and attention for the inclusion of detailed revegetation monitoring to be included in the very beginning of project design, and especially post project monitoring for long term sustainability of erosion control. There are a few studies underway to determine what types of protocols are best applied in the Tahoe Basin.

B. Bioassessment

Bioassessment is an evaluation of the condition of a waterbody using biological surveys and other direct measurements of the resident biota in surface waters. This section summarizes LTIMP's recommendations for bioassessment procedures, provides contact information for key bioassessment practitioners, and includes references to current bioassessment guidance documents.

Bioassessment relies on one or more measures of aquatic community assemblages to make inferences about the status or trend in biological integrity. The most common organisms used in bioassessment are benthic macroinvertebrates, periphyton, and fish.

There are several practitioners currently using bioassessment in the Lake Tahoe Basin. The most common methods utilize benthic macro-invertebrates to assess the biological condition of streams. However, standardized protocols are also available from the U.S. Environmental Protection Agency for bioassessments using periphyton and fish (USEPA 1999), for bioassessment in lakes and reservoirs (USEPA 1998a), and for bioassessment in wetlands (USEPA 1996, 1998b).

When conducting bioassessments to evaluate the biological integrity of specific sites, practitioners often rely on comparisons of a "test" site to a nearby "reference site" (or group of reference sites). "Reference sites" are sites with minimal human influences that have similar physical characteristics (i.e., stream size, slope, geology, etc.) to the site being tested. When the goal is to evaluate a specific project (such as a restoration project), baseline or "pre-project" condition can also be compared to post-project condition to measure changes over time. In this situation, it is also necessary to collect bioassessment data at unaffected nearby reference (or "control") sites in order to track natural (i.e., temporal) variability. That is, the practitioner needs to design the study to determine whether any changes detected at the restored site are in fact due to restoration activities (versus natural variability). One common design in such situations is the "BACI" design ("before-after, control-impact").

<u>*Protocols*</u>

(1) The protocols most commonly used throughout the State of California are the *California Stream Bioassessment Procedures*, or "CSBPs." The California Department of Fish and Game (CDFG), other state and local agencies, citizens' groups, and others use this method widely. **<u>Contact</u>:** Jim Harrington, CDFG, or obtain protocols via the Internet at: http://www.dfg.ca.gov/cabw/protocols.html

(2) Researchers at the University of California's Sierra Nevada Aquatic Research Lab (UC-SNARL) have developed a methodology that is more intensive than the CSBPs, and are using that method throughout the eastern Sierra Nevada, including the Tahoe Basin. This method is currently being used by UC-SNARL, under contract with the Lahontan Regional Water Quality Control Board, to develop reference conditions for streams throughout the eastern

Sierra Nevada.
Contact: Tom Suk, Lahontan RWQCB, or obtain protocols and quality assurance procedures via Internet at:
http://www.swrcb.ca.gov/rwqcb6/files/QAPP/QAPP.htm

(3) The U.S.D.A. Forest Service (USDAFS) has contracted with scientists at Utah State University to develop a bioassessment method for use by the USDAFS. That method is currently being tested by the USDAFS throughout the western United States, including the Lake Tahoe Basin. **Contact:** Joseph Furnish, USDAFS, or obtain more info at: http://www.usu.edu/buglab

(4) A simplified bioassessment method has also been developed for use by citizens' groups, schools, and other educational institutions. The simplified method is titled *The California Streamside Biosurvey*, and copies are available free of charge from: Citizen Monitoring Program, Division of Water Quality, State Water Resources Control Board, P.O. Box 100, Sacramento, CA 95812-0100. **Contact:** David Herbst, UC-SNARL, or obtain a copy via Internet at:
http://www.swrcb.ca.gov/nps/docs/FinRevCAStreamBiosurvey.doc

There are additional practitioners in California who are using other bioassessment methods for special studies or their particular needs. However, the above methods are currently the most commonly used on the California side of the Lake Tahoe Basin.

The State of Nevada, Division of Environmental Protection (NDEP) initiated a statewide Bioassessment Program in 2000. As of the summer of 2002, the State of Nevada will have sampled approximately 100 sites throughout the State on an annual basis. The program has included bioassessment of macroinvertebrates and periphyton; assessment of physical habitat; and evaluation of chemical parameters in the water column for all major water basins in the State. These basins have included the Colorado, Carson, Walker, Truckee, Humboldt, Snake and Tahoe Basins. Tributary monitoring, in addition to the monitoring of the main stems has been included as an additional aspect to the Bioassessment Program. Monitoring sites will be sampled annually for a period of 4 to 5 years to establish baseline conditions and to assess aquatic health.

Eight to ten bioassessment monitoring sites are slated to be monitored by NDEP in the fall of 2002 for the Eastern slopes of the Tahoe Basin. The sites will be monitored annually for a minimum of 4 to 5 years. The selection of those sites will be in coordination with other agencies within the Tahoe Basin but are expected to be based on both upper and lower elevation sites on Nevada's major tributaries to the Lake.

NDEP has adopted the "*California Stream Bioassessment Procedures* " (CSBP) for macroinvertebrate monitoring and physical habitat evaluations. The State has slightly modified the CSBP in that the samples of 3 individual riffles (9 sub-samples) are combined together to represent a composite sample of the reach. The State has also included the measurements of flow, dissolved oxygen saturation, percent riparian vegetation and type, land-use and obvious/potential non-point source pollution within the established reach. NDEP is expected to include more intense quantitative physical habitat parameters as the program advances.

Reference site criteria for conditions and site selection are being conducted by NDEP in coordination with the Nevada Bioassessment Steering Committee. The committee is composed of various other government agencies, tribal representatives, academia, and NPDES dischargers. The goals of the committee are to exchange bioassessment information, promote bioassessment within the state, and to assist the state in the selection of reference sites.

LTIMP Recommendations

LTIMP recognizes that various practitioners may need to utilize different bioassessment methods depending on the specific questions to be answered. However, LTIMP recommends that practitioners conducting bioassessments in the Tahoe Basin consider using, as appropriate, one of the four primary methods currently in use (outlined above), to facilitate the comparability of data between studies. LTIMP also strongly recommends that all bioassessment practitioners implement, as part of their project, the USEPA's Performance-Based Methods System (PBMS), so that the bioassessment data collected by all practitioners can be comparable to the greatest extent possible. The PBMS is described in Chapter 4 of the USEPA's latest bioassessment guidance document (USEPA 1999).

Contacts and References

Following are contacts and references that may be useful for persons planning to conduct bioassessment in the Lake Tahoe Basin:

Contacts:

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References:

U.S. Environmental Protection Agency. 1996. *Wetlands: Biological Assessment Methods and Criteria Development Workshop, Proceedings*, Sept. 18-20, Boulder, CO. Available at USEPA website: http://www.epa.gov/owow/wetlands/wqual/bcproc.html

U.S. Environmental Protection Agency. 1998a. *Lake and Reservoir Bioassessment and Biocriteria*. USEPA Office of Water (4504-F), Washington, DC 20460. EPA 841-B-99-002. (Free copies can be obtained by calling 1-800-490-9198, or via the Internet at: http://www.epa.gov/owow/monitoring/tech/lakes.html

U.S. Environmental Protection Agency. 1998b. *Wetlands Bioassessment Fact Sheets*. USEPA Office of Water (4502-F), Washington, DC 20460. EPA 843-F-98-001. (Free copies can be obtained by calling 1-800-490-9198, or via the Internet at: http://www.epa.gov/owow/wetlands/wqual/bio_fact/

U.S. Environmental Protection Agency. 1999. *Rapid Bioassessment Protocols for Use in Wadeable Streams and Rivers: Periphyton, Benthic Macroinvertebrates, and Fish*. Second Edition. USEPA Office of Water (4503-F), Washington, DC 20460. EPA 841-B-99-002. (Free copies can be obtained by calling 1-800-490-9198, or via the Internet at: http://www.epa.gov/owow/monitoring/rbp/

U.S. Geological Survey *Methods for sampling fish communities as part of the National Water-Quality Assessment Program* (Meador and others, 1993).

U.S. Geological Survey *Revised methods for characterizing stream habitat as part of National Water-Quality Assessment Program* (Fitzpatrick and others, 1995).

U.S. Geological Survey *Methods for collecting algal samples as part of the National Water-Quality Assessment Program.* (Porter, S. D. and others, 1993).

U.S. Geological Survey *Guidelines for quality assurance and quality control of fish taxonomic data collected as part of the National Water-Quality Assessment Program* (Walsh and others, 2000).

U.S. Geological Survey *Methods for characterizing stream habitat as part of National Water-Quality Assessment Program* (Meador, M. P. and others 1993).

9. QUALITY ASSURANCE/QUALITY CONTROL

The EPA website has a number of publications for quality control documents at (http://www.epa.gov/quality1/qa_docs.html). Some general overview pages are included in Appendix I and a list of additional references. Depending on the size of the project, Quality Assurance (QA) samples can be as little as 1-5 or as many as 20-30. The sample plan should include a section for the QA, and cost for analysis should be included in the budget. When possible, it is recommended that a grab sample be taken at the same time the auto sampler is collecting, in order to verify auto sampler effectiveness and representativeness. In regards to sample analysis and lab procedures, it is recommended that the contract lab be either a state certified lab for California or Nevada, or the lab participate in a blind reference program such as the USGS Standard Reference Program, see website http://bqs.usgs.gov/srs/.

10. REFERENCES

Buchanan, T.J. and Somers, W.P. 1976. *Discharge measurements at gaging stations*: U.S. Geological Survey Techniques of Water-Resources Investigations (TWRI), Book 3, chapter A8, 65p.

Buchanan, T.J. and Somers, W.P. 1978. *Stage measurement at gaging stations:* U.S. Geological Survey TWRI book 3, chapter A7, 28 p.

Caltrans/Larry Walker Associates. 2000. *Guidance Manual: Stormwater Monitoring Protocols (revised).* CTSW-RT-00-005. 5/00, 14 sec.

Develop purpose & objectives, site, constituent, methods & equipment selection, Sampling and Analysis Plan, equipment installation and maintenance, training, prep & logistics, sample collection, QA/QC, lab prep & analytical methods, and data reporting. .

Carter, R.W. and Davidian J., 1977. *General Procedure for gaging streams:* U.S. Geological Survey TWRI book 3, chapter A6, 13p. USGS-Tim Rowe,

Cuffney, T. F. and others. 1993. *Methods for collecting benthic invertebrate samples as part of the National Water-Quality Assessment Program*: U.S. Geological Survey Open-File Report 93-406, 66p.

Sampling design, methods for collecting, maintenance of sampling equipment, sample processing & labeling, field data sheets, safety.

Cuffney, T. F. and others. 1993. *Guidelines for the processing and quality assurance of benthic invertebrate samples collected as part of the National Water-Quality Assessment Program*. U.S. Geological Survey Open-File Report 93-407, 80 p.

Sample processing strategy.

Edwards, T.K. and Glysson, G.D. 1988. *Field Methods For Measurement Of Fluvial Sediment*: U.S. Geological Survey Open-File Report 86-531, 118 p.

Sediment sampling equipment & techniques

Guy, H.P. 1977. *Laboratory Theory and methods for sediment analysis*: U.S. Geological Survey TWRI Book 5, chapter C1, 58 p.

Herbst, D. 1999. *Bioassessment Sampling Procedures,* Sierra Nevada Aquatic Research Laboratory.

Horowitz, A. J. and others. 1994. *U. S. Geological Survey Protocol for the collection and processing of surface-water samples for the subsequent determination of inorganic constituents in filtered water*. U.S. Geological Survey Open-File Report 94-539, 57 p.

Protocol for the collection and processing of surface-water samples for the subsequent determination of inorganic constituents in filtered water.

Hunter, D.A., Reuter, J.E. and Goldman C.R., 1993. *Standard Operating Procedures – LTIMP. Draft. Laboratory analysis of nutrients, iron, TSS, turbidity, conductivity, and pH*. UCD-TRG, 79 p. 2/93.

Kennedy, E.J. 1983. *Computation of continuous records of stream flow*: U.S. Geological Survey TWRI book 3, chapter A13, 53p.

Lapham, W. W. and others. 1995. *Ground-water data-collection protocols and procedures for the National Water-Quality Assessment Program: selection, installation, and documentation of wells, and collection of related data*. U.S. Geological Survey Open-File Report 95-398, 69p.

Selection, installation, and documentation of wells, and collection of related data, and measurement of water levels and collection of additional hydro geologic and geologic data.

Meador, M. P. and others. 1993. *Methods for characterizing stream habitat as part of National Water-Quality Assessment Program*. U.S. Geological Survey Open-File Report 93-408, 48 p.

Stream habitat sampling design, methods for characterizing stream habitat.

Porter, S. D. and others. 1993. *Methods for collecting algal samples as part of the National Water-Quality Assessment Program*. U.S. Geological Survey Open-File Report 93-409, 39 p.

Sampling design, methods for collecting, sample processing & labeling.

NRCS/Clausen, J. C, 1996, NRCS *National Handbook of Water Quality Monitoring. Part 600 National Water Quality Handbook.* 13 chap.

Problem & objectives, statistical design, scale, variable selection, sample type, sampling location, sampling frequency & duration, station type, sample collection & analysis, land use & management monitoring, data management.

Shelton, L. R., 1997. *Field Guide for collecting samples for analysis of volatile organic compounds in stream water for the National Water-Quality Assessment Program.* USGS Open-File Report 97-401, 14p.

Preparation, equipment cleaning, sample collection, field measurements, QA/QC, documentation, sample ID, shipping.

Shelton, L. R., and P. D. Capel. 1994. Guidelines for collecting and processing samples for stream bed sediment for the analysis of trace elements and organic contaminants for the National Water-Quality Assessment Program. U.S. Geological Survey Open-File Report 94-458, 20p.

Study design, planning, equipment, cleaning, sample collection, sample processing, field documentation, final cleaning, QA/QC.

Tetra Tech, Inc./U.S. Environmental Protection Agency. 1998. *Techniques for Tracking, Evaluating, and Reporting the Implementation of Nonpoint Source Control Measures – III*. Urban. US EPA Office of Water - US EPA 841-B-97-011, 6 chap.

Methods to inventory BMP implementation, sampling design, methods for evaluating data, conducting evaluation, presentation of evaluation results. US EPA Web page.

U.S. Environmental Protection Agency. 1991. *Compendium of ERT Surface Water And Sediment Sampling Procedures, Sampling Equipment Decontamination, Surface Water Sampling, and Sediment Sampling.* Interim Final, Environmental Response Team, Emergency Response Division, Office of Emergency and Remedial Response, U.S. Environmental Protection Agency, Washington, DC 20460, pp. 31.

U.S. Environmental Protection Agency. 2000. *Nutrient Criteria - Technical Guidance Manual – Rivers and Streams*. US EPA Office of Water - EPA-822-B-00-002, 9 chap.

Stream system classification, select variables, sampling design for new monitoring programs, building a database, analyze data, criteria development, management programs, monitoring & reassessment of nutrient criteria ranges, case studies, methods of analysis for water quality variables, statistical tests & modeling tools. US EPA Web page.

U.S. Geological Survey. 1998. National *Field Manual for the Collection of Water-Quality Data*. Techniques of Water-Resources Investigations- Handbooks for Water-Resources Investigations, Book 9, A1-A9, 2 volumes, variously paged.

Preparation, equipment, cleaning, collection, processing, measurements for surface and groundwater sampling and biological indicators, bottom materials and safety.